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RETRIEVATION AND SELF-MENDING DAMAGED ASPHALT PAVEMENT USING HELIANTHUS

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Abstract - Ensuring the durability of pavement is essential for road safety and minimizing maintenance costs. This study explores the incorporation of Helianthus, a self-mending agent, into asphalt to improve its self-repair capabilities. Three pavement models were evaluated: one with pure asphalt and two with Helianthus-infused asphalt, added either during the mixing and heating process or after the pavement had been laid. Comprehensive testing, including Aggregate Impact Value, Specific Gravity, Penetration, and Marshall Stability tests, confirmed the high quality of the materials used. The results demonstrated significant self-healing properties, especially when Helianthus was integrated during the initial mixing process, achieving defect recovery rates of 54.74% after 15 days and 74.49% after 30 days. In contrast, post-laying addition of Helianthus resulted in recovery rates of 48.70% and 62.85%, respectively. These findings underscore Helianthus as an effective and economical solution for enhancing pavement longevity and reducing maintenance requirements. Further research on increasing Helianthus content and extending the healing period is recommended to optimize its effectiveness.

Keywords: Pavement durability, Self-mending agent, Helianthus, Asphalt, Road maintenance, Defect recovery, Bitumen.

1. INTRODUCTION

Pavement, a durable surface material for roads and walkways, comes in two main types: flexible (bitumen/asphalt) and rigid (concrete). Asphalt, a sticky, black, and highly viscous liquid, can sustain significant plastic deformation due to its binder's viscous nature. However, it is prone to fatigue from repeated loading, leading to common failures like potholes and ditches. These potholes can cause severe damage to vehicles and pose significant safety hazards, particularly for motorcycles, where the impact can be equivalent to a collision at 35 mph. Poor drainage in the roadbed, often exacerbated by heavy spring thaws, weakens the base course and contributes to fatigue cracking. Traditional methods to rectify potholes involve either removing and replacing defective pavement or overlaying the affected area, both of which increase maintenance costs.

Self-mending asphalt technology presents an advanced solution to these issues. This technology allows the pavement to self-repair defects, enhancing the overall durability and lifespan of the road surface. Techniques for self-mending asphalt include the use of rejuvenators, nanoparticles, and induction heating. Rejuvenators are particularly promising for efficient pavement revival, while induction heating uses agents like glass fiber to restore the pavement. Helianthus, a simpler self-mending agent, offers an economical and effective alternative. The research into self-mending asphalt focuses on studying the factors affecting asphalt pavement, its properties, and selecting appropriate self-mending agents. It involves comparing traditional pavement methods with self-mending techniques, both during the heating and mixing process and after the pavement has been laid.

Self-mending materials have the built-in ability to automatically repair damage without external intervention. These materials counteract degradation by initiating repair mechanisms in response to micro-damage, adapting to environmental conditions, and reducing the need for periodic manual inspections. By preventing cracks and potholes, self-mending asphalt technology enhances road safety, reduces maintenance costs, and contributes to eco-friendliness by lowering CO_2 emissions. This innovative approach holds significant potential for improving the longevity and safety of pavement infrastructure.

2. LITERATURE REVIEW

Ali Azhar Butt et al. (2012) developed a model to understand bitumen's self-healing capacity based on chemo-mechanical parameters, concluding that optimized pavement design can reduce energy consumption and emissions. Jian Qui et al. (2012) introduced a modified direct tension test to evaluate the cracking and healing behavior of bituminous mastics, finding significant differences between polymer-modified and conventional mastics. Schangen et al. (2013) enhanced porous asphalt road durability using induction heating with steel fibers, improving the material's self-healing properties. Raquel Barassa et al. (2014) explored the use of encapsulated rejuvenators to restore aged pavement properties, enhancing self-mending by releasing rejuvenators upon contact with bitumen. Dr. Devesh Tiwari et al. (2014) found that glass fiber reinforcement in asphalt mixes increased resistance to cracking and deformation, improving pavement properties. Tariq Ali et al. (2014) emphasized using waste plastic as a bitumen modifier to develop sustainable road infrastructure with lower maintenance needs. Prof. Haasan Baaj et al. (2016) reviewed cracking in bitumen roads, focusing on factors affecting pavement design and the efficacy of self-mending techniques. THAO Dinh Nguven et al. (2016) discussed self-mending mechanisms in asphalt, highlighting promising methods like induction heating and capsule healing for preventive maintenance. Daquan Sun et al. (2017) provided a comprehensive overview of self-mending mechanisms and models in asphalt, advocating for energy-based and novel material-based healing systems. Miss Gauri Mahajan et al. (2017) summarized self-mending technologies in asphalt, including rejuvenators, nanoparticles, and induction heating, emphasizing their benefits in cost reduction and environmental impact mitigation.

3. METHODOLOGY

In this research, pavement was designed under three distinct conditions and compared. *Case 1*: involved the conventional method of road pavement construction. *Case 2*: incorporated self-mending agents during the mixing and heating process. *Case 3*: introduced self-mending agents after the pavement had been laid. Various tests on pavement materials such as aggregates and bitumen were conducted to ensure quality and performance.

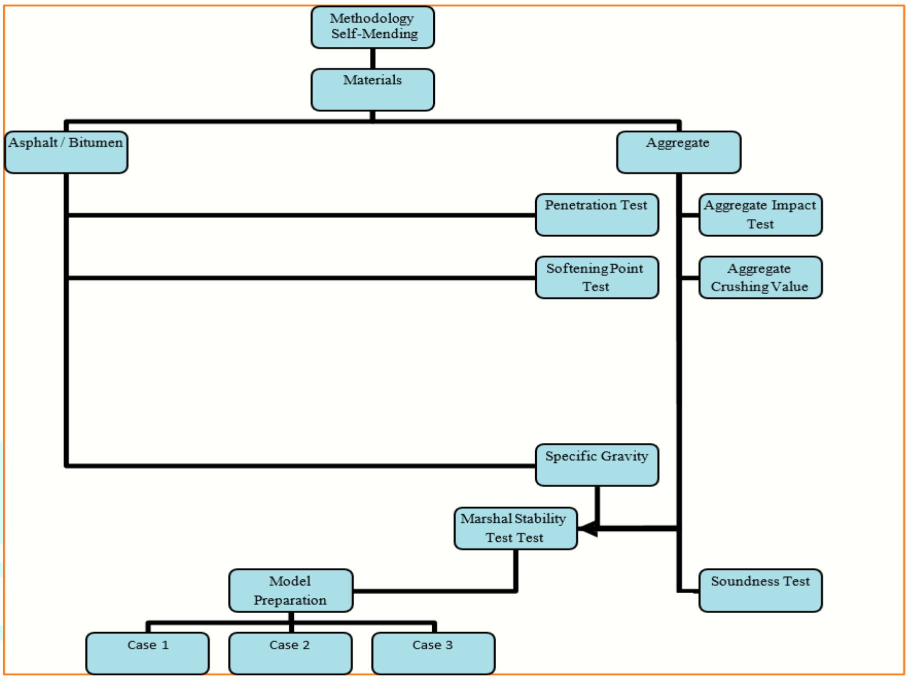

Fig 1: Process Flow Diagram

3.1. Tests on Aggregates

3.1.1. Impact Test:

Fig 2: Impact Test Appratus

The aggregate impact test assessed the resistance to impact of aggregates. Aggregates passing through a 12.5 mm sieve and retained on a 10 mm sieve were used. The material was placed in a cylindrical steel cup and subjected to 15 blows from a metal hammer. The percentage of material passing a 2.36 mm sieve after impact was calculated as the impact value. Acceptable values varied depending on the pavement type, with a maximum of 30% for wearing courses .

3.1.2. Crushing Value Test:

This test determined the crushing strength of aggregates under a compressive load. Aggregates in a surface-dry condition passing a 12.5 mm sieve and retained on a 10 mm sieve were used. The material was placed in a cylindrical measure in three layers, each tamped 25 times. The cylinder was then subjected to a load of 40 tons. The percentage of fines passing a 2.36 mm sieve after loading was calculated as the crushing value.

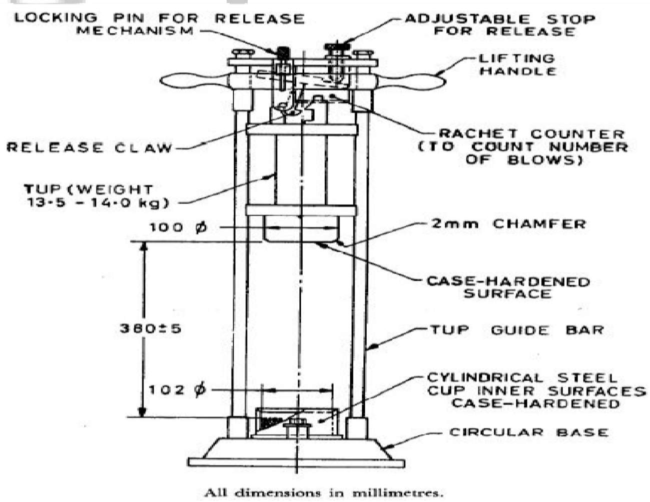

Fig 3: Crushing Value Test Appratus

3.1.3. Shape Tests:

Flakiness Index:

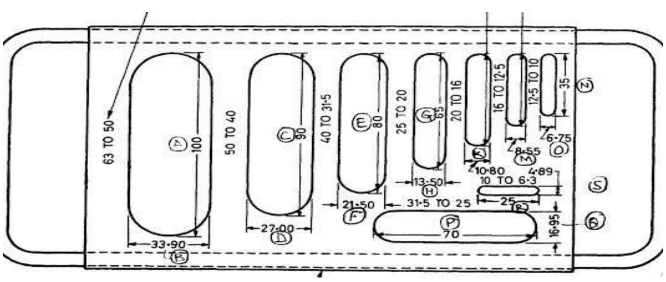

Fig 4: Flakiness Test Appratus

This test measured the percentage by weight of flaky particles, which are less than 0.6 times their mean dimension. Aggregates were sieved, and at least 200 pieces of each fraction were tested using a thickness gauge. The weight of flaky particles was compared to the total sample weight to calculate the flakiness index .

Elongation Index:

Fig 5: Elongation test Appratus

This test assessed the percentage by weight of elongated particles, which are greater than 0.8 times their mean dimension. Aggregates were gauged for length, and the weight of elongated particles was compared to the total sample weight to determine the elongation index .

3.2. Tests on Bitumen

3.2.1. Penetration Test:

This test measured the consistency of bitumen by determining the depth a needle penetrated under specific conditions. Bitumen was heated, poured into a container, and cooled. The needle was then allowed to penetrate the bitumen under a specified load and temperature for 5 seconds. The penetration value indicated the bitumen's hardness .

Fig 6: Penetration test Appratus

3.2.2. Ductility Test:

Fig 7: Ductility Test Appratus

The ductility of bitumen was measured by the distance it elongated before breaking when pulled apart at a specified temperature. The bitumen was melted, poured into a mould, and cooled. The specimen was then stretched in a ductility testing machine until rupture, and the elongation distance was recorded.

3.2.3. Flash and Fire Point Test:

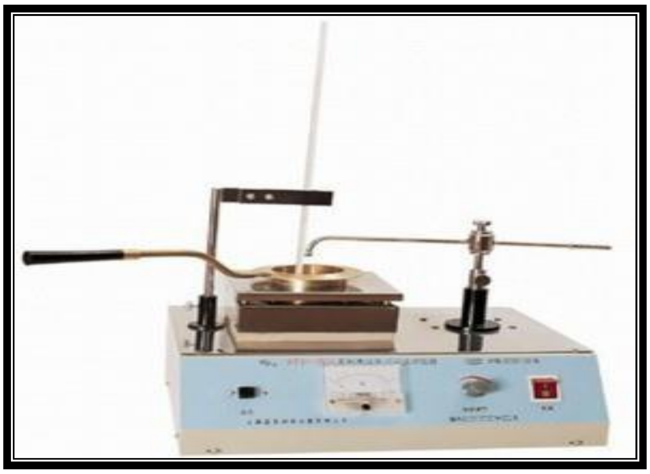

Fig 8: Flash and Fire Point Test Appratus

This test determined the temperature at which bitumen vapors would ignite. Bitumen was heated, and the temperature at which it flashed (flash point) and then continued to burn (fire point) was recorded. The flash point for different grades of bitumen was specified to ensure safety during heating.

4. RESULTS AND DISCUSSION

4.1. Aggregate Impact Value

Table 1: Aggregate Impact value

Sr.no	Description	Sample 1	Sample 2
1	Total Wt. of Dry sample taken = W1	336	332
2	Wt. of Portion passing 2.36mmAggregate = W2	64	62
3	Aggregate Impact Value = W2/W1*100	19	18.7
4	Aggregate Impact Value % = (average)	18.9	

The Aggregate Impact Value (AIV) test results, which indicate the resistance of aggregates to sudden impacts, were determined as follows: Sample 1 had a total dry weight (W1) of 336 g, with 64 g passing the 2.36 mm sieve (W2), resulting in an impact value of 19%. Sample 2 had a W1 of 332 g and W2 of 62 g, yielding an impact value of 18.7%. The average AIV across both samples was 18.9%, indicating a good resistance to impact for the aggregates used in the pavement.

4.2. Specific Gravity Test

The specific gravity test for 10 mm and 20 mm aggregates was conducted according to IS:2386 part 6. The results showed a specific gravity of 2.80 for 10 mm aggregates and 2.76 for 20 mm aggregates.

Sr. no.	Description	Unit	Result: Sample 1	Sample 2	Sample 3
1	Penetration test	mm	38	45	40
2	Penetration test	mm	38	45	40
3	Penetration test	mm	38	45	40
Average			38	45	40

These values suggest a consistent and adequate density for the aggregates, which is essential for achieving the desired pavement stability and durability.

4.3. Penetration Test

Table 2: Penetration Test

The penetration test results for bitumen, which measure its hardness or softness, were as follows: Sample 1 had a penetration value of 38 mm, Sample 2 had 45 mm, and Sample 3 had 40 mm. The average penetration values were consistent across samples, with Sample 1 averaging 38 mm, Sample 2 averaging 45 mm, and Sample 3 averaging 40 mm. These results meet the standard specifications for bitumen used in road construction, indicating that the bitumen has the appropriate consistency and hardness for effective pavement performance.

4.4. Marshall Stability Test

Table 3: Marshall Stability Test

Sr. No.	Test Conducted	Result			Requirement as per MORTH 5th revision Table 500-11		
		Sample 1	Sample 2	Sample 3	Viscosity Grade paving bitumen	Modified Bitumen: Hot climate	Modified Bitumen: Cold climate
1	Marshall stability at 60° (KN)	12.03	12.11	12.09	Min 9.0	Min 12	Min 10
2	Marshall flow (mm)	3	2.8	2.9	2.0 – 4.0	2.5 - 4	3.5 – 4
3	Specific gravity (Kg/m3)	2.421	2.424	2.42	-	-	-

Marshall Stability tests were conducted to determine the maximum load-carrying capacity of the bituminous mix at 60°C. The results for the samples were: Sample 1 showed a stability of 12.03 KN, Sample 2 showed 12.11 KN, and Sample 3 showed 12.09 KN. All values met the minimum requirement of 9.0 KN for hot climates and 12 KN for cold climates as per MORTH standards. The Marshall flow values, indicating the deformation of the mix under load, ranged from 2.8 mm to 3 mm, which is within the specified range of 2.0 to 4.0 mm. The specific gravity values were around 2.421, indicating a dense and compact bituminous mix suitable for road construction.

4.5. Defect Healing in Pavement Model

The study investigated the self-healing properties of asphalt by incorporating Helianthus self-mending agents. Two cases were studied: adding Helianthus during the mixing and heating process (Case 1) and adding it after pavement laying (Case 2).

Table 4: Case 1

Defects	Length (mm)	Breadth (mm)	Depth (mm)	Volume (mm^3)	Recovery (%)
Initial stage	70	20	25	35000	-
After 15 days	66	12	20	15890	54.74
After 30 days	62	9	16	8928	74.49

Case 1: Adding Helianthus During Mixing and Heating

Initial defect dimensions: 70 mm length, 20 mm breadth, 25 mm depth (volume 35,000 mm^3).

After 15 days: Defect dimensions reduced to 66 mm length, 12 mm breadth, and 20 mm depth (volume 15,890 mm^3), resulting in a recovery of 54.74%.

After 30 days: Defect dimensions further reduced to 62 mm length, 9 mm breadth, and 16 mm depth (volume 8,928 mm^3), achieving a recovery of 74.49%.

Table 5: Case 2

Defects	Length (mm)	Breadth (mm)	Depth (mm)	Volume (mm^3)	Recovery (%)
Initial stage	70	20	25	35000	-
After 15 days	68	12	22	17952	48.70
After 30 days	65	10	20	13000	62.85

Case 2: Adding Helianthus After Pavement Laying

Initial defect dimensions: 70 mm length, 20 mm breadth, 25 mm depth (volume 35,000 mm^3).

After 15 days: Defect dimensions reduced to 68 mm length, 12 mm breadth, and 22 mm depth (volume 17,952 mm^3), resulting in a recovery of 48.70%.

After 30 days: Defect dimensions further reduced to 65 mm length, 10 mm breadth, and 20 mm depth (volume 13,000 mm^3), achieving a recovery of 62.85%.

The results demonstrate that incorporating Helianthus during the mixing and heating process significantly improves the self-healing capacity of the pavement compared to adding it after the pavement has been laid. The enhanced recovery rates in Case 1 indicate that the self-mending agents are more effectively integrated into the asphalt matrix when mixed and heated together, leading to better healing performance over time. In Case 2, while the self-healing effect is still significant, it is less pronounced, suggesting that the integration and distribution of the healing agent within the asphalt are more critical during the initial mixing phase.

Overall, the study highlights the potential of Helianthus as an effective self-mending agent for asphalt pavements, capable of enhancing the durability and reducing the maintenance requirements of road surfaces. The findings support the adoption of such innovative materials in pavement construction to improve longevity and performance.

5. CONCLUSION

Asphalt, a black, viscous adhesive substance, is used for road pavements due to its pliability when heated and subsequent hardening upon cooling. A novel self-healing agent, Helianthus, can be mixed with asphalt to reduce its viscosity and facilitate the repair of defects in road pavements. In this study, three pavement models were prepared: one with pure asphalt and two with Helianthus-infused asphalt. The Helianthus was added in two scenarios: during the heating and mixing process, and after the pavement was laid by applying it to the defect.

The models, designed for low traffic, were subjected to a load of 58 N/cm^2. In the first scenario, healing rates were 54.74% after 15 days and 74.49% after 30 days. In the second scenario, healing rates were 48.70% after 15 days and 62.85% after 30 days. These results indicate that Helianthus exhibits significant self-mending properties, particularly when incorporated during the initial heating and mixing process of asphalt. Consequently, integrating Helianthus into asphalt during the mixing phase enhances the self-repair capabilities of pavements. Increasing the amount of Helianthus and extending the healing period could potentially lead to complete defect repair, demonstrating its efficacy as a self-healing agent in asphalt pavements.

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